Combining Active and Passive Acoustics to Study Marine Mammals

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LONG-TERM GOALS

The primary goal of this project is to build a combined active-passive acoustical system to study marine mammal behavior and habitat use in relation to ocean noise and oceanographic processes. The combined active-passive acoustical system will significantly enhance the contribution that ARL-PSU can make to research associated with understanding how ocean noise, physical processes, and biological processes contribute to marine mammal behavior and habitat use. Integrated data such as these will be vital in evaluating the effect of military sources operated in marine mammal habitats.

OBJECTIVES

The immediate goals for this project are to: 1) build three active acoustic systems to measure *in situ* zooplankton and fish abundance, 2) build three Passive Aquatic Listeners (PALs) for detecting marine mammal presence, and 3) integrate the separate acoustic systems into a combined mooring system capable of making synchronized measurements of an ocean region. The final product will be a set of three combined active-passive acoustical systems capable of concurrently measuring ocean noise levels and components, the presence of vocalizing marine mammals, acoustic backscatter from fish and zooplankton, and regional weather parameters (wind and precipitation).

APPROACH

The combined acoustical system utilizes existing active and passive acoustic instrumentation. The PALs were originally designed by Dr. Jeffrey Nystuen at the Applied Physics Laboratory at the University of Washington (APL-UW) for measuring ocean precipitation. PALs enhanced with algorithms for detecting marine mammals will be built by Nystuen for this project. The active acoustic sensors are commercially available from ASL Environmental Sciences and are called Acoustic Water Column *Profilers*™ (AWCP). Each of the three combined acoustic systems consist of one PAL and three single-frequency (125 kHz, 200 kHz, and 460 kHz) AWCPs. The acoustic systems are designed for incorporation into long-term mooring stations.

Passive Aquatic Listeners (PALs)
PALs are autonomous and depend on internal batteries for operation. Each PAL is 30 inches long by 6 inches in diameter and weighs approximately 10 lbs in water, making in deployable on almost any mooring configuration (Figure 1). It is typically mounted in a cage to avoid damage by mooring/fishing lines. Electronics consist of a low-noise wideband hydrophone, signal pre-amplifier

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and a recording computer. The PAL is not a continuous acoustic sampler. The temporal sampling strategy is designed to allow the instrument to record data for up to one year (Nystuen, 1998). The basic PAL data are a time series of spectral levels between 200 Hz and 50 kHz. These spectra are evaluated individually to determine the acoustic source and then are recorded internally. Current band-pass filters will be modified to accommodate the low frequency signals (10 – 200 Hz) generated by sea ice, baleen whales, and other transient sources in the area. The time interval between data collection sequences is variable depending on the acoustic source detected and the mission requirements. For a six month to one year deployment the default "sleep time" between samples can be set to 10 minutes, allowing a low duty cycle of 0.75% when acoustic conditions permit, but increasing to as high as 15% during periods of high acoustic activity. A short “soundbite” sampling protocol (4.5 sec) can be invoked when a signal of interest is detected (Figure 2).

Figure 1. PAL in its deployment cage.

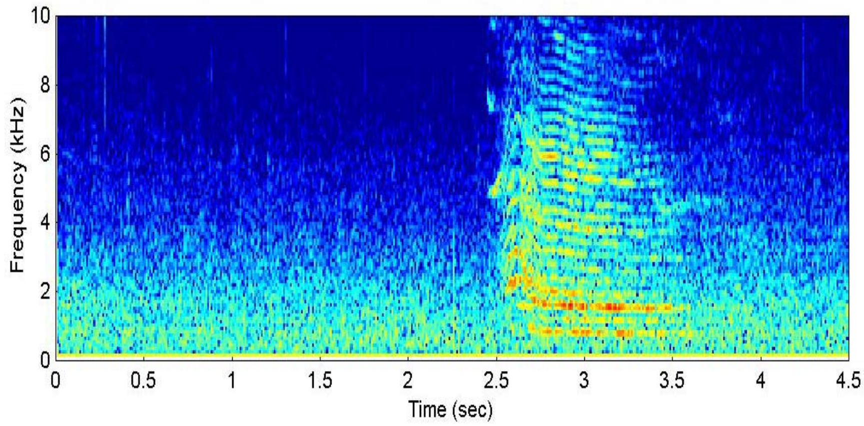

Figure 2. A 4.5 sec time series collected offshore at Cape Flattery, Apr 26, 2005. The signal shown is a transient killer whale vocalization (Nystuen, 2006).

PALs have previously been employed to monitor marine rain, wind, coastal noise, vessel traffic, and marine mammal presence at multiple locations around the globe (Ma & Nystuen, 2005; Miksis-Olds et al., 2007; Nystuen, 2006). Regional ambient sound budgets have also been constructed using PAL data (Nystuen & Howe, 2005). By examining the spectral characteristics of ocean sound, local sound sources can be identified and a sound budget for each location can produced. The sound budget details when a source is detected, the percentage of time that a particular source is present, and the loudness of that source. Spectra of marine mammals known to inhabit the local waters will be included in the PAL software for comparison to recorded spectra. When there is a match, indicating the presence of a particular species, a modified sampling protocol will be invoked to increase the sampling rate and to record sound clips.

Acoustic Water Column Profilers (AWCP)
Active acoustics have been used extensively to map the distribution of planktonic and nektonic species in the water column (Foote & Stanton, 2000; Benoit-Bird & Au, 2003). The AWCP (Figure 3) can monitor the presence and location of zooplankton and fish within the water column by measuring acoustic backscatter returns with ultrasonic frequencies (Figure 4) (Brierley et al., 2006; Kunze et al., 2006). The profilers have a vertical resolution of 0.1 m over an approximate 200 m range at 460 kHz and 500 m range at 125 kHz. Profilers are approximately 24 inches in length and 7 inches in diameter and have a dry weight of 80 lbs. For each 6-month to one year deployment, the profilers can be programmed to collect data for 5-10 minutes each hour. Using onboard data storage, the AWCP can collect data continuously or intermittently for periods of up to a year and can be operated in an upward looking orientation from the sea-bed or a subsurface mooring. The profiler can also be operated in a downward looking mode from a surface buoy. The orientation of sensors within mooring configuration will be dependent on study area location. Cages will be constructed to reduce the level of damage risk due to mooring movement in extreme conditions and to ensure the sampling of the same water parcel by each sensor.

Figure 3. AWCP

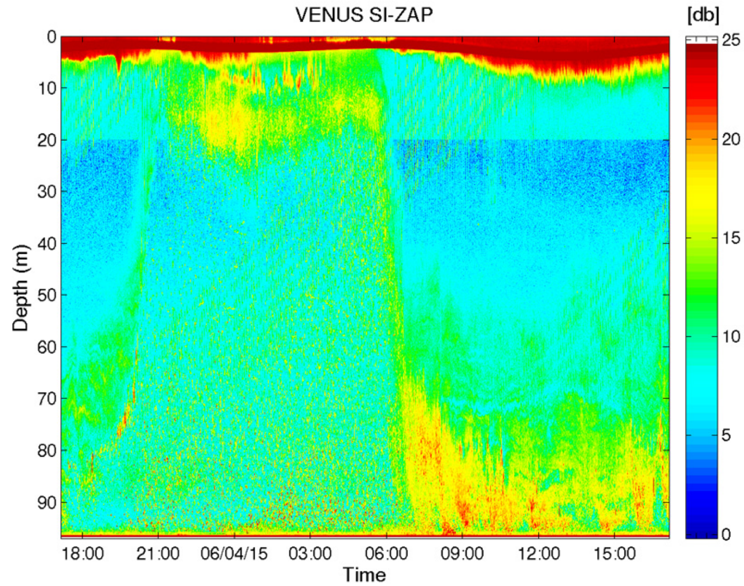

Figure 4. A 24 hour sample of zooplankton acoustic backscatter recorded with a 200 kHz AWCP from the Victoria Experimental Network Under the Sea (VENUS). The image shows a vertical migration event. The AWCP was operated in a vertical orientation facing up towards the surface. http://www.venus.uvic.ca/index/html

The temporal and vertical spatial distribution of zooplankton in the water column will be measured with AWCPs of three different frequencies (125 kHz, 200 kHz and 460 kHz). By recording acoustic backscatter from at least two frequencies, the differences in backscatter between the frequencies can be used to distinguish between different scatterers in the water column (Watkins & Brierley, 2002). The following broad taxonomic categories can be distinguished: small mesozooplankton (e.g. copepods, chaetognaths), large mesozooplankton (e.g. euphausiids), and swim-bladdered fish (Lawson et al., 2004; Warren et al., 2003).

WORK COMPLETED

During the first six months of the project, nine AWCPs (three 125 kHz, three 200 kHz, and three 460 kHz) have been built and delivered to ARL-PSU. Stainless steel mooring cages have also been designed, built, and delivered. The mooring cages mount the AWCPs at a 15 degree angle in an upward looking position. The instruments are oriented at an angle to prevent interference from the mooring line. The instruments are also positioned so that the transducer beams are collocated and imaging the same parcel of water (Figure 5).

The fabrication of three PALs has been commissioned by Jeffrey Nystuen at APL-UW. Expected delivery is December, 2008.

Field testing of the first AWCP instruments and mooring cage was conducted in Massachusetts Bay in June 2008. The active acoustic system was successfully deployed for approximately three weeks on a sub-surface mooring.

Deployment of two combined acoustic systems (previously made PALs were borrowed for this deployment until the fabrication of new PALs is complete in December 2008) was completed in September 2008. The combined acoustical systems were incorporated into NOAA sub-surface mooring in an upward looking direction at sites M2 and M5 in the Bering Sea (Figure 6). The instruments will sample for one year.

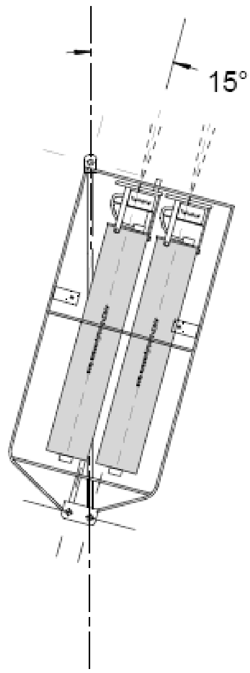

Figure 5. AWCP mooring cage. AWCP sensors are mounted in an upward looking position, 15 degrees off vertical.

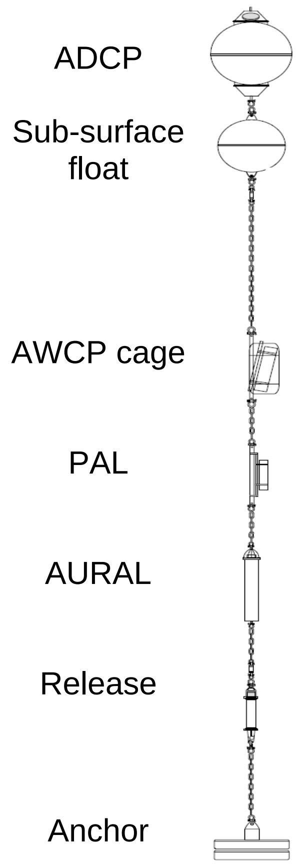

Figure 6. NOAA sub-surface mooring at sites M5 in the Bering Sea. The AWCP and PAL instruments are incorporated into the middle of the mooring. Other mooring sensors include an ADCP, continuously recording AURAL, and an acoustic release.

RESULTS

Results from the first field deployment of the AWCP mooring in Massachusetts Bay showed that there was no cross-talk or interference between the three simultaneously sampling AWCPs at 125 kHz, 200 kHz, and 460 kHz. This alleviates the need for staggering the timing of the three outgoing transducer pings during sampling, which will ensure synchronized sampling.

The buoyancy needed to support the AWCPs and mooring cage was also determined during the first field deployment. The three AWCPs with quarter battery packs plus the mooring cage weighed approximately 60 lbs in water.

IMPACT/APPLICATIONS

Scienfitic
The combined active-passive acoustical system establishes a new research capability for pre-existing moorings. The compact acoustic system fills a need for year round data collection in areas where extreme weather and/or remote locations prohibit traditional sampling methodologies of marine mammals and their prey. Such information is needed to effectively mitigate the effects of anthropogenic sound in the marine environment.

Outreach
Acquisition of the AWCPs provided motivation for the offering of a new course through the Graduate Program of Acoustics at Penn State. ACS597C Acoustic Field Measurements is being offered this Fall semester to promote hands-on learning opportunities in a field or laboratory setting. The operation of the AWCPs, as well as the data analysis software, is the focus of an active acoustics module within this course.

TRANSITIONS

The technology and methodolgies developed with this funding will aid the US Navy in addressing environmental compliance, risk assessment, and potential effects of military related noise sources on marine mammals and the marine anvironment.

RELATED PROJECTS

Cumulative and synergistic effects of physical, biological, and acoustic signals on marine mammal habitat use
PI: Miksis-Olds, ARL PSU
ONR Marine Mammal Program   Award Number: N000140810391
The goal work is to enhance the understanding of how variability in physical, biological, and acoustic signals impact cetacean habitat use.

Fine-scale focal Dtag behavioral study of diel trends in activity budgets and sound production of endangered baleen whales in the Gulf of Maine
PI: S. Parks, ARL PSU
ONR Marine Mammal Program
The goal of this research is to better understand the environmental signals driving baleen whale behavior.

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